

## **Automated Highway Systems (AHS)**

### ***What is the Opportunity?***

The idea of vehicle-highway communications sufficient to assume driving functions for the driver is not new. Researchers have articulated both its value and feasibility for several decades; and military and vehicle manufacturer test facility developments have proven the concept's viability. As mounting congestion conflicts with environmental constraints, the Automated Highway System (AHS) promise of doubling our existing highway system's capacity is worth investigating.

### ***What is an Automated Highway System (AHS)?***

The Automated Highway System (AHS) concept defines a new relationship between vehicles and the highway infrastructure.. AHS will use:

- **control technologies** that shift driving functions from the driver/operator to the vehicle
- **communications technologies** to recognize and react to the external infrastructure's real-time traffic conditions.

The AHS concept combines on-board vehicle "intelligence" with a range of "intelligent technologies" installed onto the existing highway infrastructure. The vehicles will be dual mode vehicles that can operate on both AHS and non-AHS lanes, including automobiles, buses, and trucks. The infrastructure intelligence can be allocated across a spectrum, that on the one end is highly dependent upon vehicle intelligence to the other end where the intelligence is concentrated on the infrastructure as shown in Attachment A.

### ***What are the Potential Benefits?***

The precursor studies indicate that AHS can increase the number of vehicles/lane /hour by two to three times, cut travel time by 33 to 50 percent, and potentially reduce accidents by 50 to 80 percent. The AHS consortium expects that AHS could improve driving safety, reduce congestion, reduce fuel consumption and emissions, and reduce trip times. For detailed information on benefits see Attachment B: AHS Benefits.

### ***What is the Federal Program?***

In October 1994, the Department entered a cooperative agreement with industry to further develop the AHS concept. The agreement inaugurated the National AHS Consortium (NAHSC). The NAHSC consists of public and private stakeholders with a broad range of views on AHS. Through a consensus process, the consortium will specify, develop, and demonstrate a prototype AHS and provide for evolutionary deployment that can be

tailored to regional and local transportation needs. An essential task of the consortium is to seek opportunities for early introduction of vehicle and highway automation technologies to achieve initial benefits for all surface transportation users. For a detailed review of NAHSC's work to date and future plans see Attachment C: AHS Federal Program.

### ***Long-Term Vision***

The Federal role is essential to continued development of highway automation -- supporting long-term, high-risk research and development that industry and public sector agencies cannot undertake alone. If AHS is to be successfully developed and implemented, public/private partnerships must continue to be pursued. NAHSC is working in cooperation with DOT, committing skilled resources and management energies to realizing the vision of AHS. The momentum must be maintained to realize the promise of the automated highway in operation.

By its nature a long-term R&D program, the AHS initiative has not yet altered transportation to the degree expected in the future. It has, however, already advanced the state of technology in applicable areas, notably radar target discrimination, machine vision, actuators, and control algorithm design. The program will also continue critical vehicle control, communications, and human factors research. In 1999, NAHSC will select a preferred system approach, with operational tests beginning shortly thereafter, and ultimately leading to a preferred system in 2002.

The ISTEA legislation emphasized the 1997 demonstration as an important milestone among a full program of six major milestones over the next seven years. Beyond the 1997 demonstration is the selection and prototype testing of the preferred AHS configuration. Upon completion of the systems definition phase, the preferred configuration will next undergo operational test and evaluation. The support for this phase of the program is crucial to the successful deployment of AHS. Only through operational testing can the public understand, experience, and appreciate the promise of this technology.

### ***For More Information on Automated Highway Systems***

Contact: Ray Resendes or Dick Bishop

An important milestone identified by the NAHSC workplan is the NAHSC Demonstration 97, which showcases 1997 applications of technologies, systems, and subsystems that will contribute to a future AHS prototype. The demonstration will include passenger vehicles, transit buses, and heavy trucks. The demonstration will include mini-demonstrations of some of these technologies on local surface streets. NAHSC will also cosponsor a technical conference with SAE to showcase state-of-the-art and evolving technologies that comprise critical elements of the AHS.

Even with the technological advances of the 1980s and 1990s, AHS requires an ongoing commitment to long-term research. To date, the AHS concept has benefited from continuing research and development in the defense and transportation sectors. However, the technical challenges have been so great as to yield relatively modest results until recently. Increasingly, we are now applying automation to routine, repetitious tasks so that drivers are free to pursue other objectives: Automation ensures that the chore is performed more safely, quickly, and efficiently than drivers could ever do unassisted.

Although the technologies exist to create and implement an AI-IS, it would not be desirable to move immediately to full-scale automation. AHS development will be a long-term, multi-phased process. This slow and steady approach will ensure that the work is done correctly, the right technologies are optimized, drivers can gradually become comfortable with increasingly available in-vehicle technologies, driver and industry concerns are addressed, and concurrent upgrades in the driving experience -- such as energy-efficient alternative propulsion methods -- are incorporated. Moreover, long-term implementation will ensure that the expensive technologies needed in AHS design will be significantly more cost-effective and accessible when they are used in volume.

The NAHSC workplan lays out a multi-year effort to develop and advance the critical technologies required to support a 1997 AHS demonstration; select and evaluate AHS concepts; and build and test an AHS prototype. Investment decisions are informed by a deep understanding of the current state of technology development. Where applicable, efforts build on technical capability developed by NHTSA's crash avoidance research and other elements of ITS research (e.g., vehicle-roadside communications, satellite positioning, advanced traffic management centers.)

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**Attachment A:  
AHS Technologies**

<b>Concept</b>	<b>Local Position Keeping</b>	<b>Lane Changing</b>	<b>Obstruction on Roadway</b>	<b>Flow Control</b>
Autonomous	Vehicle automatically senses vehicle ahead and roadway problems	Looks for and moves into an opening	Vehicle brakes for detected obstacles, changes lanes if possible	ITS
Cooperative	Vehicle Sensors, communications from other vehicles for lane changes or platoons	Cooperative negotiation among vehicles	Vehicle senses, communicates warning and coordinates maneuvers	ITS
Infrastructure supported	Same as cooperative, but within guidelines from the infrastructure	Same as cooperative	Infrastructure or vehicle senses, communicates to vehicles; vehicles coordinate	Infrastructure monitors traffic, formulates responses, send parameters to local groups of vehicles
Infrastructure managed	Vehicles sensors, communications from other vehicles and infrastructure as needed	Vehicle requests lane change; infrastructure responds with commands for surrounding vehicles	Infrastructure senses sends commands to vehicles based on infrastructure or vehicle detection, or vehicle actions	Infrastructure monitors individual vehicles, commands vehicles as needed, including entry and exit
Infrastructure controlled	Infrastructure sense vehicle positions and sends commands to control throttle, braking and steering	Infrastructure determines need for lane change from origin-destination data, controls all necessary vehicles	Infrastructure senses, sends commands to vehicles based on infrastructure or vehicle detection, or vehicle actions	Infrastructure monitors individual vehicles, performs optimizing strategy through control of individual vehicles.

**Attachment B:  
AHS Benefits**

Element	Benefits
Roadway Capacity	More vehicles can be accommodated on the highway. The number of vehicles per hour per lane can be significantly increased as traffic speeds are standardized and increased and headway distances are decreased. Studies estimate that two to three times more vehicles could be accommodated through elimination of inefficiencies caused by inattentiveness, merging, weaving, and lane changing.
Safety	Driving safety will be significantly greater than at present. the human error factor will be removed. Some estimates state that 50 percent improvement can be realized with AHS application.
Weather	High performance driving can be conducted without regard to weather and environmental conditions. Fog, haze, blowing dirt, low sun angle, rain, snow, darkness, and other conditions affecting driver visibility (and thus, safety and traffic flow) will no longer impede progress.
Mobility and Societal Access	<p>All drivers using AHS can be safe, efficient drivers. AHS offers enhanced mobility for people with disabilities, the elderly, and less experienced drivers.</p> <p>Participants in focus group anticipated far less stress and worry in highway travel for those using AHS, but, concerns for equity and access across society were expressed.</p>
Air Quality and the Environment	<p>Fuel consumption and emissions can be reduced. In the short term, these reductions will be accomplished because start-and-stop driving will be minimized and because on-board sensors will be monitored to ensure that the vehicle is operating at top performance. In the long term, the AHS can support future vehicle propulsion/fuel designs.</p> <p>Land can be used more efficiently. roads will not need to take up as much room, since AHS facilities should allow for more effective use of the right of way.</p>
Commercial and Transit Efficiency	<p>More efficient commercial operations. Commercial trucking can realize better trip reliability to support “just-in-time” delivery.</p> <p>More efficient transit operations. Transit operations can be automated, extending the flexibility and convenience of the transit option to increase ridership and service.</p>
Economic Gains	<p>“[The program] provides the opportunity for U.S. industry to stake out a dominant position internationally in the unique technologies that will comprise the future automated highway system.” Rodney Slater</p>

## **Attachment C: AHS Federal Program**

### *National AHS Consortium (NAHSC)*

The NAHSC's goal is to further develop the concept of AHS. The consortium consists of public and private stakeholders. Core NAHSC partners include General Motors, Bechtel Corporation, the California Department of Transportation (Caltrans), the Carnegie-Mellon University Robotics Institute, Delco Electronics, Hughes Aircraft, Lockheed Martin, Parsons Brinkerhoff, and the University of California Partners for Advanced Transit and Highways (PATH) Program. In addition, NAHSC includes close to 100 associate members who represent nine categories of stakeholders: vehicle industry, government-agencies, highway design industry, vehicle electronics, environmental interests, trucking operators, transit operators, transportation users, and the insurance industry. The associate participants in these categories engage in program activities ranging from policy management to technical development. Their contributions and expertise are invaluable in the decision-making process of the consortium.

### NAHSC Workplan

The NAHSC workplan lays out a multi-year effort to develop and advance the critical technologies required to support a 1997 AHS demonstration; select and evaluate AHS concepts; and build and test an AHS prototype. Where applicable, efforts build on technical capability developed by NHTSA's crash avoidance research and other elements of ITS research (e.g., vehicle-roadside communications, satellite positioning, advanced traffic management centers).

The workplan is organized into three phases -- analysis, system definition, and operational test and evaluation.

#### *Phase 1 -- Analysis*

During the analysis phase, numerous in-depth research studies are being conducted to acknowledge and assess all issues related to AHS design, development, and deployment. These studies fall into three groups: (1) precursor systems analyses, (2) human factors research, and (3) NHTSA-sponsored collision-avoidance analyses, focusing on vehicle warning and control services.

#### **Precursor Systems Analysis Research**

Fifteen precursor systems analysis contracts were let by FHWA to investigate the issues and risks related to AHS design, development, and implementation. Collectively, the contracts aimed at researching, analyzing, and debating a broad spectrum of AI-IS-related issues. The structure of these contracts was innovative; a matrix of 16 activity areas were

investigated by multidisciplinary, multi-organizational teams representing a wide variety of perspectives -- state and local transportation departments, academia, aerospace, and automotive industry representatives, and defense and high-tech research organizations. Specific areas these contractors are investigating are:

- AHS in urban and rural operational environments
- Certification of proper vehicle functioning for automated operation (automated check-in)
- Certification of proper vehicle and driver functioning for manual operation (automated check-out)
- Lateral and longitudinal control of an automated vehicle
- Malfunction management
- Unique AHS-related needs of commercial and transit vehicles
- Lessons learned from deployment of comparable systems
- Deployment of possible AHS configurations within existing freeway networks
- Impact of AHS on nearby non-AHS roadways
- AHS entry/exit implementation
- Ongoing AHS operation
- AHS vehicle operation, including vehicle retrofitting
- Impact of alternative propulsion systems on AHS deployment and operation
- AHS safety issues
- Institutional and societal aspects of AHS deployment
- Assessment of AHS preliminary cost/benefit factors

### **Human Factors Research**

The human factors questions surrounding AHS involves the transition from manual to automated driving and back again, normal automated driving, and handling of emergency events. The research is informed by comparable systems analyses -- looking at lessons learned from other automated roadway systems that have humans in the loop. These other systems are Germany's O-Bahn system (buses whose steering control is taken over by an automated system in narrow tunnels), the Chunnel repair vehicle (which operates on both normal and automated roadways), the Washington D.C. Metro subway system (whose automated speed control feature must sometimes be controlled manually), and airplane autopilot systems.

A key component of AHS human factors research is driving simulation using Iowa's University's highly sophisticated, motion-based driving simulator. The simulator consists of a Ford Taurus with three seamless wide screen projection systems showing realistic computer-generated roadway scenes around the vehicle and a motion system that provides the sensations of braking and accelerating.

### **NHTSA-sponsored Collision Avoidance Research**

AHS is closely coordinated with collision avoidance research to ensure that technical results are complimentary.

### *Phase 2 -- System Definition*

This phase will: (1) establish the AHS performance and design objectives and evaluate AHS concepts; (2) conduct a full-scale demonstration in 1997 of AHS technical feasibility as required by ISTEA; (3) select a preferred system approach; (4) demonstrate, test, evaluate a prototype of the preferred AHS approach; and (5) prepare documentation for this configuration.

The Department expects that the system-definition phase will last through 2001 or 2002. At the conclusion of this phase, all specification and documentation needed for product developers and transportation agencies to develop AHS will be available.

### *Phase 3 -- Operational Test and Evaluation*

One or more implementations of the preferred AHS approach will be evaluated at selected U.S. locations in several operational settings. It will be integrated into the current into the current institutional, technological, regulatory, and highway environment. This phase will take place early in the next century.

Since the inception of NAHSC in 1994, the consortium has completed a Systems Description Document that defines AI-IS goals, objectives and functions; initiated identification and evaluation of AHS approaches and to identify a small set of concepts; prepared a detailed work plan for the 1997 AHS technology prototype demonstration; launched research into institutional issues; and conducted outreach, including three major workshops for research. The first workshop was aimed at augmenting stakeholder involvement and fortifying their representation in the NAHSC. The other two workshops were held for concept selection and garnered the expertise of the transportation community. another noteworthy accomplishment is the tripling of the number of associate participants. A kick-off ceremony was held at the site of the first AHS demonstration -- the I-15 Express Lane in San Diego County, California -- on June 28, 1996. In addition, the program is conducting two case studies evaluating the effects of automated transit and commercial vehicle operations.